Fermi National Accelerator Laboratory

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Study of the Structure of the Events Produced in Soft $\bar{p}p$ Interactions at $\sqrt{s} = 1800$ GeV

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Abstract

In this note preliminary results on a systematic study of the event structure dependence on the event multiplicity and/or event average p_t are presented. The mean p_t, the short range pseudorapidity correlations and the mean sphericity are analysed as a function of the event multiplicity. The mean sphericity and the mean multiplicity are studied as a function of the event average p_t.

The basic phenomena and the detailed dynamics which underlie the production of hadronic multibody final states are essentially unknown. In soft hadronic multiparticle production, a large amount of experimental data has been accumulated during many years of experimental studies. These data give a more or less detailed empirical description of many of the features of the multibody events. Still several aspects of the particle correlation phenomena are unclear and the interplay of various kind of correlations as well as it systematic evolution with the centre of mass energy, event tranverse energy and multiplicity, require more extended and deep studies. QCD, which has to deal with the nonperturbative regime which dominates in this kind of interaction, inspired many theoretical models. But it fails to give an exhaustive, unitary description of multibody formation processes.

CDF is a multipurpose apparatus working at the highest $\bar{p}p$ collider energy presently in operation. We present here the first preliminary results of a study

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aimed at a systematic analysis of various kind of particle correlations as a function of the event multiplicity and transverse momentum in soft $\bar{p}p$ interactions at $\sqrt{s} = 1800$ GeV. The purpose of this study is to look for any indication which can characterize the global event structure of the soft $\bar{p}p$ interactions and its evolution towards harder parton interations.

The results presented here come from a sample of about 360,000 minimum-bias triggers recorded during 1988/89 data taking period. The minimum-bias trigger required an East-West coincidence in two sets of scintillator counters located symmetrically at 5.82 m from the nominal interaction point and covering the η interval $3.2 < \eta < 5.9$. The details of the CDF apparatus and of the minimum-bias trigger are published elsewhere[1]. Here only some features relevant for the present analysis are described. Tracks are measured in the CTC (Central Tracking Chamber). The CTC measures p_t, η and ϕ of each track with high resolution and good efficiency ($\Delta p_t/p_t \simeq 0.003$; $\varepsilon \simeq 99$ %) in the intervals: $\mid \eta \mid < 1$ and $p_t > 0.4$ GeV/c. During the 1988/89 run, an inner tracking system of time projection chambers (VTPC, Vertex Time Projection Chamber) was operative. This system covered the η interval from about -3.0 to 3.0. It measured the η of each track, but did not measure the track p_t and gave a poor measure of ϕ. In this paper we present results on the average p_t, on the strength of the short-range two particle pseudorapidity correlations and on the mean sphericity analysed as functions of the charged multiplicity of the event. The mean sphericity and the mean multiplicity are also studied as a function of the event average p_t.

In the following the event average p_t is defined as:

$$\overline{p_t} = \frac{1}{n}\sum_{j=1}^{n} \mid p_t \mid_j \tag{1}$$

where n is the charged event multiplicity and $\mid p_t \mid_j$ the transverse momentum af the j^{th} track. Unless otherwise stated they are both measured in the η, p_t intervals quoted above.

The dependence of the average p_t on the event particle density (defined as: $n/\Delta\eta$) is showed in fig.1a. Since its first observation by UA1[2], this dependence has been measured at various energies and for different reactions[3, 4, 5].

From figure 1a we observe that the rise of the average p_t with the multiplicity is not linear. After a steeper rise at the lower particle densities it follows a weaker increase starting at a particle density of about 3. In order to check

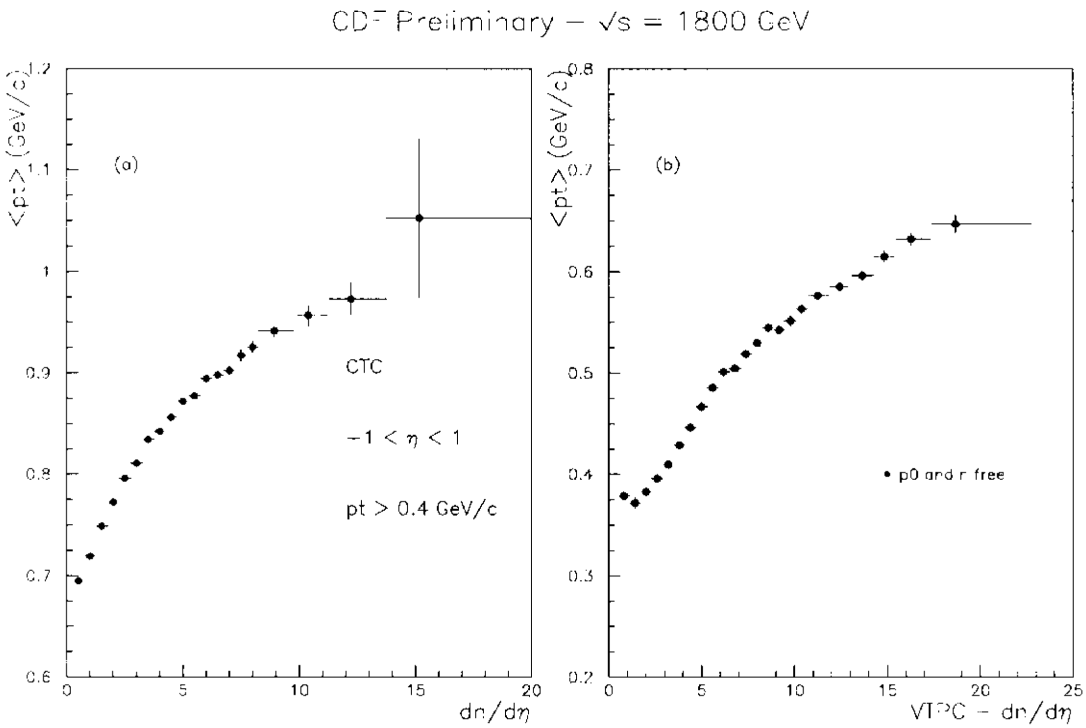

Figure 1: Fig.1a - Average p_t versus particle density. Both the quantities are evaluated from charged tracks in the $\mid \eta \mid \leq 1.0$ and $p_t > 0.4$ GeV/c ranges. The mean p_t is computed through formula (1) of the text. Fig.1b - Average p_t versus VTPC particle density. The particle density is here measured from VTPC tracks in the η interval $\mid \eta \mid \leq 2.5$ and the average p_t values are obtained fitting the distribution of the CTC measured p_t to the form (2) of the text.

that the behaviour of the data of figure 1a is not just a consequence of the cuts imposed by the CTC, the true multiplicity was measured in the interval $-2.5 < \eta < 2.5$ using the VTPC. Since the VTPC cannot measure the track p_t, the average p_t was evaluated making the p_t distribution of the CTC tracks for each VTPC fixed multiplicity and then fitting the obtained distribution to the form:

$$\frac{d\sigma}{dp_t^2} = A\left(\frac{p_t^0}{p_t - p_t^0}\right)^n \tag{2}$$

in which A, p_t^0 and n are free parameters and the average p_t is determined from their fitted values. Fig.1b shows the average p_t computed in this way as a function of the particle density measured in the VTPC. With respect to fig.1a the data have of course a lower average p_t and the particle density is smeared on a larger interval. Qualitatively the shape of the dependence seems to be preserved.

Since the average p_t increases with the particle density we wonder if also the particle correlations change with increasing event multiplicity.

The two particle pseudorapidity correlation measures the tendency of particle pairs in multiparticle final state to be emitted close in rapidity, within a range of 1 or 2 units. The semi-inclusive correlation function (the adjective semi-inclusive indicates that one is referring to a sample of fixed multiplicity, n, events) is defined by:

$$\mathrm{C_n}(\eta_1, \eta_2) = \rho''_{\mathrm{n}}(\eta_1, \eta_2) - \rho'_{\mathrm{n}}(\eta_1)\rho'(\eta_2) \tag{3}$$

where:

$$\rho'_{\mathrm{n}}(\eta) = \frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}\eta} = \frac{1}{\mathrm{N}}\frac{\Delta \mathrm{n}}{\Delta\eta}$$
$$\rho''_{\mathrm{n}}(\eta_1, \eta_2) = \frac{1}{\sigma}\frac{\mathrm{d}^2\sigma}{\mathrm{d}\eta_1 \mathrm{d}\eta_2} = \frac{1}{\mathrm{N}}\frac{\Delta_{\mathrm{n}12}}{\Delta\eta_1\Delta\eta_2}$$

are the single and two particle pseudorapidity densities, Δn is the number of tracks in $\Delta\eta$, Δn_{12} is the number of pairs in $\Delta\eta_1$ and $\Delta\eta_2$ and N is the number of events. Function (3) differs from zero if the joint production of particle pairs differs from the independent production of two particles with the same pseudorapity values. With the form defined in equation (3), the correlation function is normalized to -n. In order to measure the strength of the correlation, the behaviour $C_n(\eta_1, \eta_2)$ is examined at fixed values of η_2, as a function of η_1. In this way the correlation effect appears as a peak in the correlation function at $\eta_1 \simeq \eta_2$. The height of the peak is sligtly independent on the value of η_2, at least when η_2 moves in a small pseudorapidity range. The correlation strength can then be measured by averaging the peak values of the correlation function at $\eta_1 = \eta_2$ for various values of η_2. When examined at fixed value of η_2, the integral of $C_n(\eta_1, \eta_2)$ over η_1 gives $\rho'_n(\eta_2)$. So in order to compare the strength of the semi-inclusive correlation at different multiplicities, the average height of the correlation peak, computed as stated before, has been divided by ρ'_n (0). Let us call this quantity A, for practical reasons:

$$A = \frac{\overline{C_n}(\eta_1, \eta_2)}{\rho'_n(0)} \tag{4}$$

This quantity has been plotted in fig.2 as a function of dn/dη. The strength of the correlation increases with increasing dn/dη. This is expected from previous measurements [6] [7] [8]. Within the present errors is not possible to say whether the rise with dn/dη is linear or not.

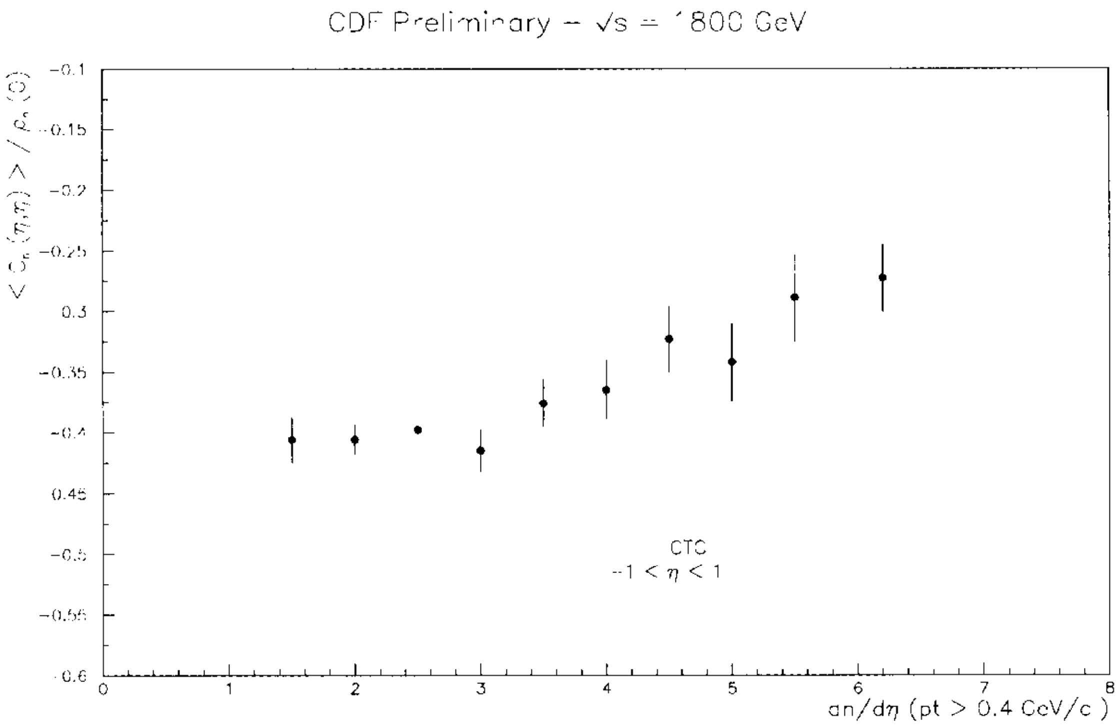

Figure 2: The strength of the semi-inclusive two particle pseudorapidity correlation divided by ρ_{n^I} (0) plotted versus dn/dη.

Variables like the sphericity are especially suited to describe the features of the global shape of the event particle distribution. In fig.3 the mean sphericity is shown as a function of the particle density. As written above all the quantities in fig.3 have been computed using CTC tracks, so they are restricted to the phase-space intervals stated above. The mean sphericity increases with increasing particle density with a steep rise for the first low multiplicity points followed by a weaker increasing rate.

The relation between the average p_t and the multiplicity showed in fig.1a has been analysed using the event average p_t as the independent variable; the results are shown in fig.4. It is to be remarked that computing the mean multiplicity for all the events having an average p_t in a given interval implies a

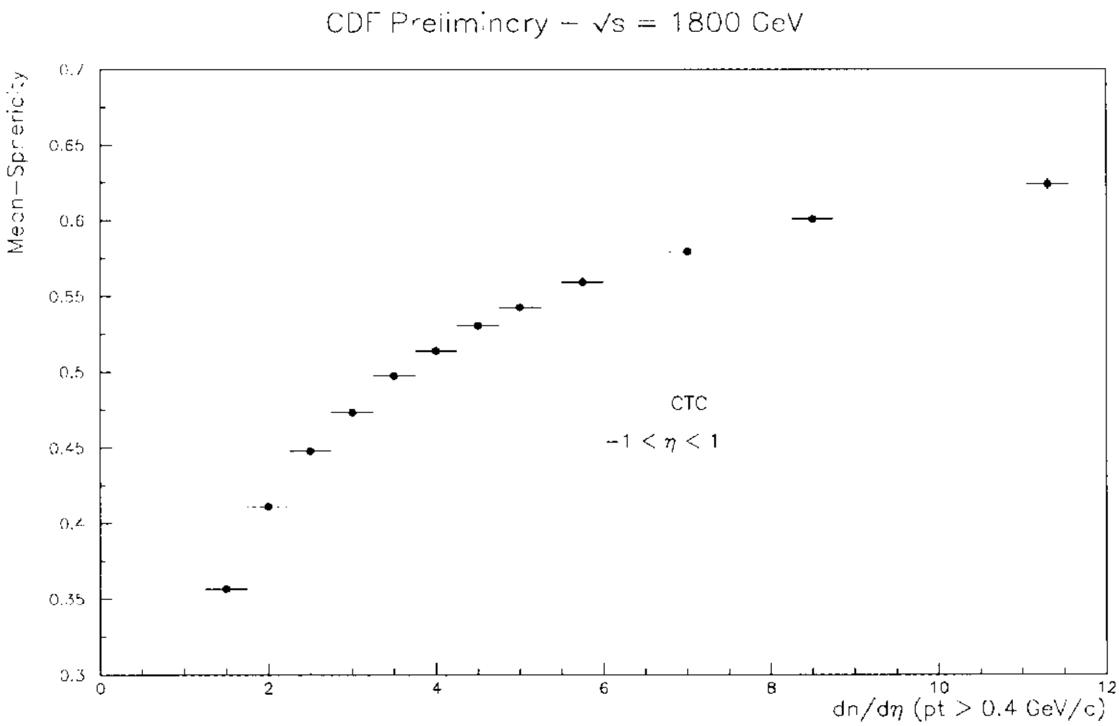

Figure 3: CTC track mean sphericity in η interval $\pm$ 1 versus dn/dη.

different event classification with respect to what is done to obtain the points of figure 1a. In fig.4 we see that the mean multiplicity rises with increasing event $< p_t >$ up to a peak at $< p_t >$ about 1 GeV/c and mean multiplicity of about 7, then it falls down and remains almost flat at a value of about 2.5 for $< p_t >$ greater than 1.5 GeV/c. The events in this high $< p_t >$ tail are only about 2.8 % of the total events in fig.5.

The mean sphericity is plotted in fig.5 again as a function of the event $< p_t >$. Also the mean sphericity has its maximum at a $< p_t >$ around 1 GeV/c then falls down and remains nearly flat for $< p_t >$ greater than 1.5 GeV/c.

The multiplicity distribution obtained using the VTPC tracks in the η interval -2.0 $< \eta <$ 2.0 for all the events with $< p_t >$ greater than 1.4 GeV/c in fig.5 is compared in fig.6 with the same distribution for the events with $< p_t >$ less than 1.4 GeV/c. The two plots of fig.6 are in KNO variables and show the quoted multiplicity distributions in linear scale (fig.6 a) and in logarithmic scale (fig.6b). The shapes of the two distributions are slihtly different, par-

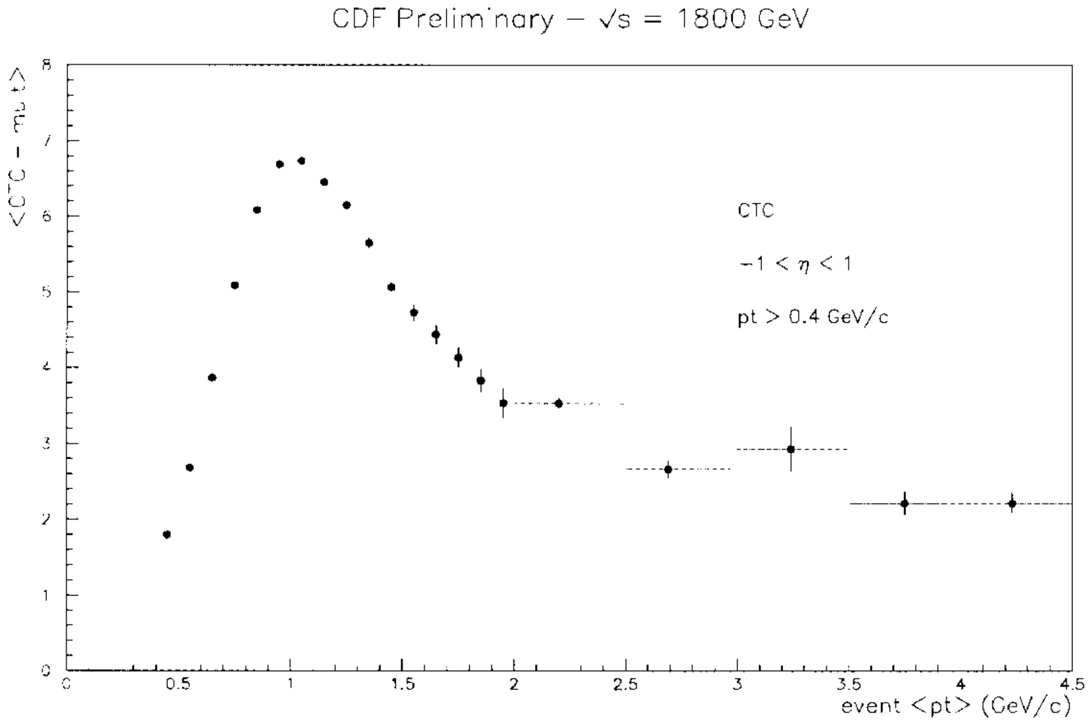

Figure 4: The mean multiplicity is plotted against the event average p_t. CTC tracks in $|\eta| \leq 1.0$ and with $p_t > 0.4$ GeV/c are used. The $< p_t >$ is computed through formula (1) of the text.

ticularly in the peak region where the data for events with $< p_t >$ greater than 1.4 GeV/c show a narrower and a little higher peak. The distribution for events with $< p_t >$ less than 1.4 GeV/c is practically coincident with the correspondent distribution of the full minimum-bias sample.

As written above we are performing a systematic study of different kind of particle correlations and of the characteristics of the global event shape as a function of the same quantities (particle density, event average p_t and event transverse energy). The aim is to look for any change in the behaviour of the event structure which may be taken as an indication of the on setting of the hard parton interaction. This requires very high statistics. At present only the data collected in the 1988/89 run have been analysed. A larger data sample, recorded during the 1992/93 run is under analysis. We can summarize the preliminary results presented here as follows.

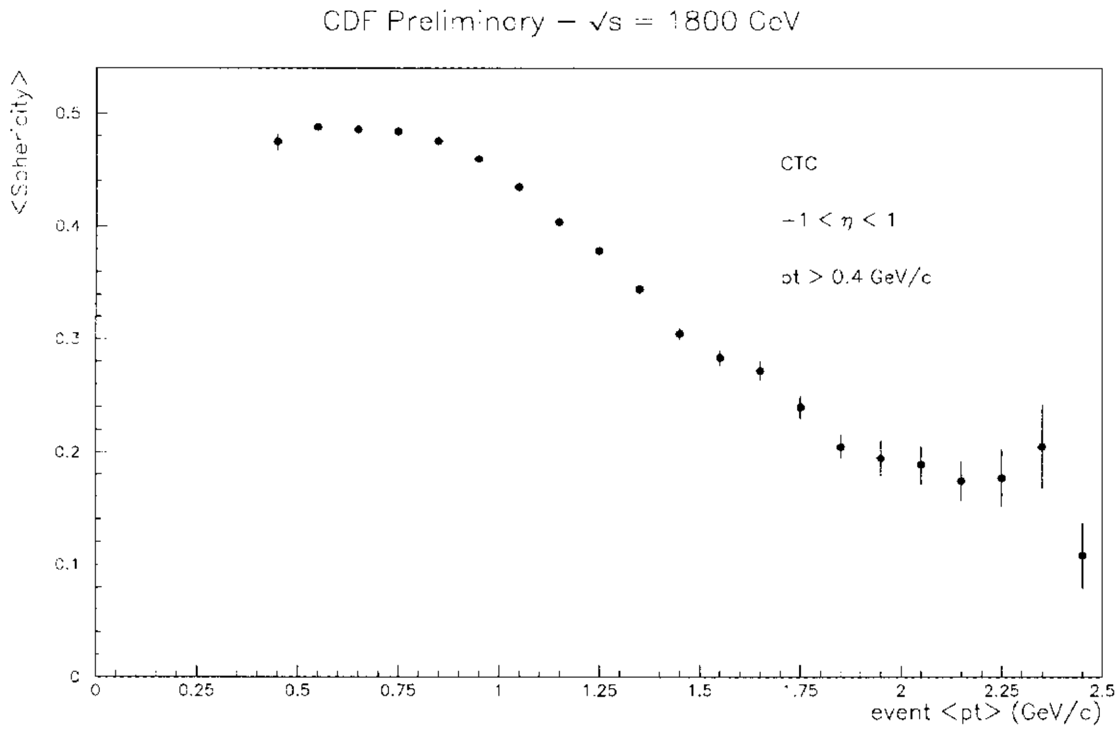

Figure 5: The mean sphericity is plotted against the event average p_t. CTC tracks are used as in fig.4.

The $\bar{p}p$ minimum-bias interactions at $\sqrt{s} = 1800$ GeV show an event average p_t which, when measured in the η and p_t regions: $-1.0 < \eta < 1.0$ and $p_t > 0.4$ GeV/c respectively, gathers around a peak which has its maximum at $< p_t >$ around 1 GeV/c and fall down at about 1.5 GeV/c. The mean multiplicity, analysed as a function of the event average p_t, goes up to about 7 ($\Delta n/\Delta\eta = 3.5$) at $< p_t >$ around 1 GeV/c, dropping to about 2.5 at $< p_t >$ around 1.5 GeV/c and then keeping constant for larger $< p_t >$. The mean sphericity, when analysed as a function of the same variable, shows a rather similar behaviour. It could be possible to extend the phase-space to which this measure is currently limited by using the VTPC information. Looking at the properties of the minimum-bias events as a function of the event multiplicity, all the quantities, mean p_t, strength of the short range pseudorapidity correlations and mean sphericity rise with the event multiplicity. The rise is not linear and has its maximum curvature at $\Delta n/\Delta\eta$ between 3 and 6.

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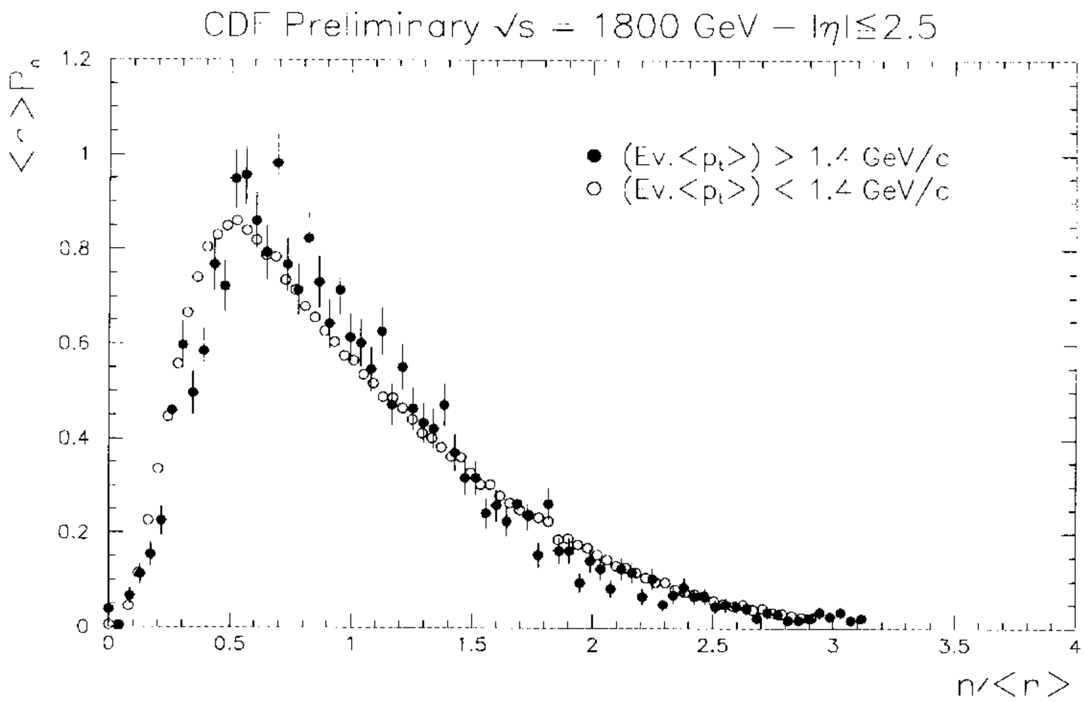

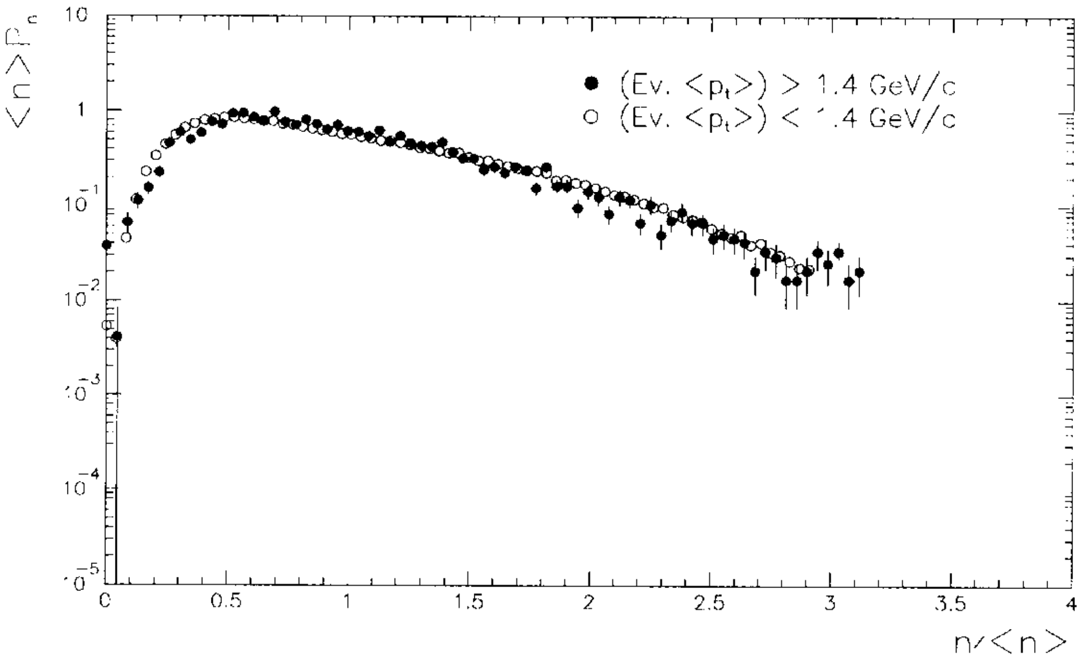

Figure 6: Multiplicity distributions for all the events with event average $p_t \leq 1.4$ GeV/c (black circle) and event average $p_t > 1.4$ GeV/c (open circle). VTPC tracks in the interval $|\eta| \leq 2.5$ are used. The distributions are in KNO variables plotted on linear scale (fig.6a) and on logarithmic scale (fig.6b).